

## Heavy Metals Contamination and its Toxic Health Effects in Edible Green Leaf Vegetables Collected from Selected areas in Kaura Namoda, Zamfara State, Nigeria

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### ABSTRACT

Green vegetables and fruits contain essential nutrients for human development, especially when they are free from contamination, such as heavy metals, which can be a concern due to environmental pollution. The present research examines the levels of heavy metal concentration in green vegetable and fruit samples purchased from Kaura Namoda market, Zamfara State. Acid digestion and AAS were used for sample preparation and analysis. While the hazard index was also calculated using the internationally recommended values. The results show that the orange samples have only two heavy metal contaminations, Zn and Fe, with concentrations of  $0.144 \pm 0.001$  mg/kg and  $0.264 \pm 0.420$  mg/kg, respectively. In tomato and cabbage, pumpkin and spinach, all the selected heavy metals, namely Ni, Cd, Cr, Pb, Fe, Cu, and Co, were detected, but within the WHO recommended limit, except cabbage and tomatoes, where the Pb concentration, 0.142 mg/kg and 0.335 mg/kg respectively, are higher than the WHO recommended value. On the other hand, the hazard index indicates that cabbage and tomatoes may pose a health risk, as their hazard indices are 1.611 and 2.66, respectively. Therefore, continued monitoring of vegetables and fruits from Kaura Namoda is essential for adequate information about the heavy metal contamination.

**Keywords:** Vegetables; Fruits; Heavy Metals; Pollutant; Soil; Hazard Index; WHO; Kaura Namoda.

### 1. Introduction

Fruits and vegetables are one of the natural dietary foods that provide all the essential nutrients required for both adults and children to grow. Fresh fruits and vegetables contain important minerals such as iron, potassium, zinc, and copper, which are crucial for various biochemical processes in the body. They also contained vitamins such as vitamins A, B, and C for human growth and development, and vitamins for healthy growth [1].

Fruits and vegetables are planted by farms in large quantities either by irrigation during the dry season, in order to make them available for commercial purposes. Different varieties of fruit and vegetables are grown in different parts of the country. Therefore, fruits and vegetables are made available to consumers by the fruit retailer [2].

Different researchers globally have reported the heavy metal contamination of fruit and vegetables. Heavy metals are found in the soil and water as a result of human activities, industrial pollution, and improper waste management. [2]. They are taken up by the plant either from the soil or from the irrigated water used for the irrigation of the fruit and vegetables. The content of mineral elements and other nutrients from the vegetables and fruit is mainly determined by the characteristics of the soil where the vegetables are planted [3].

Vegetables make up the majority of people's daily diets worldwide. Urban civilization has been using leafy vegetables more recently. However, in developing agriculture and vast natural marine and terrestrial environments, heavy metals like As, Cd, Cr, Cu, Ni, and Pb are the most common contaminants of vegetables consumed [4]. Our primary food source is vegetables, but nothing is known about the concentration of heavy metals in the native vegetables that humans eat. Therefore, the purpose of this study was to evaluate the levels of heavy metals in various edible vegetables and identify any health hazards associated with consuming them daily [5].

According to [6], [7], [8]. Heavy metals like Cu and Ni are categorized as essential trace elements that are known to play a significant role in biochemical actions, such as plant physiology, plant growth, electron transport, and redox reactions. They are also known to contribute to the development of various metabolic activities in plants. Low levels of heavy metals like As, Cd, and Pb, however, can cause a variety of problems for vegetables and their consumers, as well as be hazardous and contaminate the environment.

The buildup of heavy metals hurts plant phytochemistry and physiology, which results in modifications to the concentration of secondary metabolites or active components in plants [9]. Furthermore, signs of toxicity from an excess of heavy metals include Chlorosis, limited growth, browning of the roots, and ultimately plant death. Large-scale arsenic consumption can cause a variety of ailments, including skin cancer, gangrene, leucomelanosis, non-pitting edema, hepatomegaly, and splenomegaly, as well as abnormalities of the neurological system and cardiovascular system. Problems with the heart, kidneys, and respiratory system can result from high concentrations of Cd. Exposure to elevated levels of Cr can result in several illnesses [10].

### **1.1. Effects of Heavy Metals on Vegetable Quality**

Variations in stain concentration, liquid content, and dehydration are indicative of the varying responses of vegetation to nutrients and metal concentrations, development, and weight. It is possible to use the various light absorption and reflectivity characteristics that result from these changes in plant attributes to identify soil contamination and the physiological state of the plants. According to [11] study findings, metal and nutritional anxiety in plants cause variations in the supernatural reflectivity of the undergrowth. These variations may have a variety of biological effects on the plants and, as a result, influence the growth or reduction of nutritional availability in vegetables. Metal toxicity in plants results in substantial reductions in rates and strong germination inhibition [12].

### **1.2. Harmful Effects of Heavy Metals on Human Health**

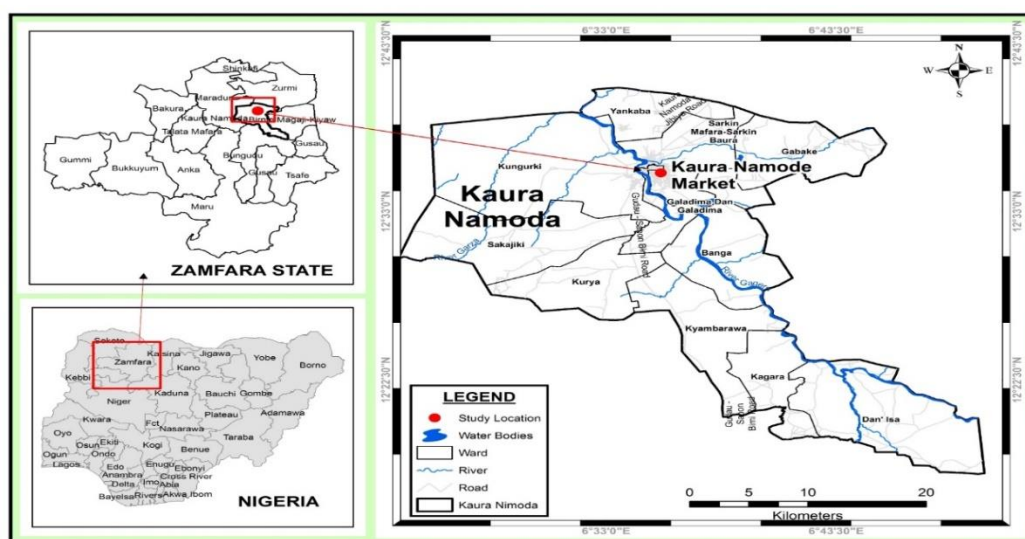
Because heavy metals will negatively affect human health and the sustainability of food, there is serious worry about their presence in soil, air, and water. Consuming large quantities of vegetables contaminated with metals can cause a range of illnesses in their consumers. Eating vegetables is the main way that humans become contaminated with heavy metals [13]. Food contamination with heavy metals can cause heavy metal accumulation in the kidneys and livers of people, upsetting several biochemical processes that can result in diseases related to the heart, nervous system, kidneys, and bones [14]. There is growing concern about human intake of toxic metals, even at low concentrations, which in turn leads to bioaccumulation in the body and leads to malfunction of organs and the system in general [15]. The environmental pollution with toxic heavy metals is due mainly to human activities, such as illegal mining and agricultural activities [2]. Plants and animals take these toxic metals from the soil into the food chain. Continue monitoring of toxic metals in edible vegetable leaves in our environment will provide information on the level of environmental pollution. This, in turn, helps to design a means of mitigation of this toxic metal from our environment [16].

This research aims to determine the concentration and toxicity of heavy metals in green edible leafy vegetables and fruits obtained from selected villages in Kaura Namoda local government, Zamfara state.

## 2. Materials and Methods

### 2.1. Study Area

Kaura Namoda is the head headquarters of the Kaura Namoda local government area. Home of Federal Polytechnic Kaura Namoda, it has 868km and an estimated population of 281,367 as at the 2006 census. The central market, where all the other local governments in the senatorial zone are situated, at Kaura Namoda town. Fruit and vegetables are sold in the central market by different vendors who purchase mainly from other states, as far as south southwest of Nigeria, where some of the fruit, such as mango, orange, papaya, pineapple, and other vegetables like pumpkin leaves.



**Figure 1.** Map of Zamfara State, Showing Kaura Namoda and Kaura Market where Samples were collected

### 2.2. Sample collection

The fruit and vegetable samples were obtained from different fruit vendors in the Kaura Namoda metropolis. The samples are watermelon, orange, pineapple, tomato, pepper, cabbage, onion, bitter leaves, water leaves, scent leaves, pumpkin, and spinach.

**Table 1.** Botanical names of each sample collected from Kaura Namoda Market, Zamfara state

| Samples     | Botanical Name              |
|-------------|-----------------------------|
| Water melon | <i>Citrullus lanatus</i>    |
| Orange      | <i>Citrus sinensis</i>      |
| Pineapple   | <i>Ananas comosus</i>       |
| Tomato      | <i>Solanum lycopersicum</i> |
| Pepper      | <i>Capsicum annum</i>       |
| Cabbage     | <i>Brassica oleracea</i>    |
| Onion       | <i>Allium cepa</i>          |
| Bitter leaf | <i>Veronica amygdaline</i>  |
| Water leaf  | <i>Talinum triangulare</i>  |
| Scent leaf  | <i>Ocimum gratissimum</i>   |
| Pumpkin     | <i>Telfairia accident</i>   |
| Spinach     | <i>Amaranthus hybridus</i>  |

### 2.3. Sample preparation and digestion

The samples were rinsed with distilled water to remove dirt and dust from the leaves. The samples were now dried in the laboratory at room temperature. The dried samples were ground and sieved to obtain a powder.

The acid digestion procedure was adopted in this research as the standard analytical method for sample preparation. The principle of this technique is that the acid would break down the organic matter and the complex matrices into a simple one.

The sample of fruit, such as oranges, pineapples, and watermelons, with a high level of sugar and an acidic matrix, foams vigorously with concentrated HCl and the excess residue of carbon. The whole edible part of the fruit was cut into pieces after peeling the skin. The juice was extracted and filtered to remove the sharps. The filtrate was freeze-dried and ground into powder. 4g of the samples was weighed in a cleaned beaker, and nitric acid was added as the primary oxidant, followed by hydrogen peroxide as the auxiliary oxidant in order to control the foam and complete oxidation.

About 0.6g of the powder samples was weighed into a cleaned 100 ml beaker, and 5 ml of concentrated nitric acid  $\text{HNO}_3$  was shaken to dissolve, there after 2 ml of perchloric acid  $\text{HClO}_4$  was added. The solution was digested by heating at a low temperature using a hot plate at 70 °C until the brown foam disappeared. Thereafter after it was removed and allowed to cool, and dissolved in 2ml of 1% nitric acid for AAS analysis. The blank sample was also prepared in the same method for the quality control. Each sample was analyzed in triplicate for accuracy and precision, and the average of each sample's results was calculated, including the standard deviation.

The principle of atomic absorption spectroscopy (AAS) is based on the Beer-Lambert law, where a free atom in its ground state absorbs light at a specific wavelength, and the absorbance is directly proportional to the concentration.

$$A = \log I_0/I$$

### 2.4. Assessment of Health Risk

The carcinogenic risk of the selected heavy metals to human beings was calculated using the estimated daily intake of metals EDI and hazard quotient. The accumulated non-carcinogenic health hazard was also computed using the hazard index HI. The equation below was used for the calculation

$$EDI = \frac{C \times IR}{BW} \quad (1)$$

$$HQ = \frac{EDI \times EF \times ED}{AT \times RFD} \times 10^{-3} \quad (2)$$

EDI = estimated daily intake (mg/per/day).

C= heavy metal concentration (mg/kg).

IR = injection rate.

BW = Average body weight 70 kg.

EF = exposure frequency (365days).

ED = exposure duration 70 years.

AT = average time of exposure.

RFD = Oral references.

### 3. Result and Discussion

**Table 2.** Concentration of Heavy Metals in Vegetable and Fruit Samples (mg/kg)

| Sample      | Ni          | Cd          | Cr           | Pb           | Zn          | Fe          | Cu          | Co          |
|-------------|-------------|-------------|--------------|--------------|-------------|-------------|-------------|-------------|
| Watermelon  | 0.024±0.004 | 0.000±0.00  | 0.005 ±0.001 | 0.002 ±0.001 | 0.233±0.008 | 0.421±0.008 | 0.025±0.005 | 0.031±0.008 |
| Orange      | 0.00±0.00   | 0.000±0.00  | 0.00±0.000   | 0.00±0.00    | 0.144±0.001 | 0.264±0.420 | 0.000±0.00  | 0.000±0.00  |
| Tomatoes    | 0.018±0.004 | 0.027±0.005 | 0.014±0.008  | 0.335±0.032  | 0.148±0.006 | 0.034±0.012 | 0.245±0.046 | 0.030±0.008 |
| Pepper      | 0.023±0.001 | 0.107±0.001 | 0.005±0.001  | 0.007±0.001  | 0.132±0.049 | 0.026±0.004 | 0.214±0.001 | 0.044±0.009 |
| Cabbage     | 0.017±0.005 | 0.011±0.004 | 0.064±0.006  | 0.142±0.009  | 0.355±0.046 | 0.354±0.047 | 0.345±0.004 | 0.015±0.008 |
| Onion       | 0.014±0.009 | 0.008±0.004 | 0.00±0.000   | 0.046±0.004  | 0.153±0.005 | 0.229±0.009 | 0.097±0.041 | 0.017±0.001 |
| Bitter leaf | 0.00±0.000  | 0.00±0.00   | 0.012±0.001  | 0.002±0.001  | 0.142±0.001 | 0.145±0.001 | 0.213±0.001 | 0.00±0.000  |
| Scent leaf  | 0.00±0.000  | 0.007±0.002 | 0.00±0.000   | 0.00±0.00    | 0.232±0.002 | 0.431±0.002 | 0.134±0.002 | 0.00±0.000  |
| Water leaf  | 0.012±0.004 | 0.003±0.004 | 0.003±0.004  | 0.021±0.001  | 0.211±0.002 | 0.421±0.002 | 0.101±0.001 | 0.011±0.001 |
| Pumpkin     | 0.021±0.001 | 0.023±0.002 | 0.013±0.002  | 0.015±0.001  | 0.165±0.002 | 0.431±0.001 | 0.121±0.001 | 0.013±0.001 |
| Spinach     | 0.012±0.004 | 0.016±0.004 | 0.023±0.002  | 0.023±0.002  | 0.172±0.001 | 0.230±0.002 | 0.431±0.002 | 0.015±0.001 |
| FAO/WHO     | 0.01        | 0.2         | 0.3          | 0.3          | 99.4        | 425.5       | 73.3        | -           |

Concentration of the heavy metals in vegetables and fruits from Kaura Namoda market, Tabulated in Average Means and Standard Deviation. Where, 0.00 shows not detected.

The concentration of heavy metals in the selected vegetables and fruit samples was analyzed in triplicate, and the average value of each sample's results was calculated as shown in Table 2 above. According to the table, Ni, Cr, Pb, Zn, Fe, Cu, and Co were detected in the watermelon samples, whereas Cd was not detected. Only two heavy metals, namely Zn and Fe, were detected in the orange. Orange does not grow in the northern part of Nigeria; all the commercial oranges available in Kaura Namoda were mainly purchased in wholesale quantities from the southern part of Nigeria. All the selected heavy metals were detected in the tomato samples. Among the heavy metals detected, Zn and Cu had high concentrations of  $0.148 \pm 0.006$  and  $0.245 \pm 0.046$ , respectively. The presence of heavy metals was also reported by [3] in Maiduguri, Borno State, Nigeria. In their findings, they reported the presence of Cr, Cu, and Pb in the watermelon samples obtained from Maiduguri, Borno State, but the concentration of heavy metals reported is lower than the concentration of heavy metals reported in the present study. Watermelon is largely produced in the northern part of Nigeria in large quantities, which are usually transported to other parts of Nigeria. The role of watermelon in the body such hydration, because watermelon contains 92% water, which, when adequately eaten it prevents dehydration. It also contained vitamins A, B6, and C, which play a vital role in body defense, healthy skin, and metabolism.

All the selected heavy metals in this present research were detected in cabbage and onion samples. The heavy metals are Ni, Cd, Cr, Pb, Zn, Fe, Cu, and Co; their concentration vary, where Zn and Cu have high concentrations

of 0.355 mg/kg and 0.354 mg/kg, respectively. The onion samples have a higher concentration of Fe (0.229 mg/kg). This trend of heavy metals in vegetables and fruit was reported by several researchers. [17] reported the presence of heavy metals in onion samples from Bauachi state of Nigeria; in their findings, Cr and Pb are higher in concentration above the maximum limit of WHO/ FDA. However, these vegetables are produced throughout the season in the northern part of Nigeria, mostly by an irrigation system, as reported by [3,15]. Cabbage contains a lot of vitamin C and K, which are vital for the development of the immune system and bone strength [18]. Onions contain anti-inflammatory and antimicrobial properties.

Among the vegetable samples analyzed for heavy metals are scent leaf, water leaf, bitter leaf, and pumpkin, which are vegetables regularly consumed by households for meals day by day. Bitter leaf contained Pb, Cu, Zn, and Fe. Out of the eight heavy metals analyzed. In scent leaf, Ni and Pb are not detected. This may be a result that scent leaves are mostly grown within households or in small gardens, unlike spinach and waterleaf, which are farmed in large quantities because of consumer demand [19]. Pumpkin, popularly called Ugu leaf and spinach, is mostly farmed by irrigation because it is readily available throughout the seasons [20].

**Table 3.** Estimation of Hazard Quotient and Health Risk Index

| Sample      | THQ Ni | THQ Cd | THQ Cr | THQ Pb | THQ Zn | THQ Fe | THQ Cu | THQ Co | HI      |
|-------------|--------|--------|--------|--------|--------|--------|--------|--------|---------|
| Watermelon  | 0.098  | ND     | 0.015  | 0.0619 | 0.0590 | 0.0120 | 0.0410 | 0.0023 | 0.2892  |
| Orange      | ND     | ND     | ND     | ND     | 0.0180 | 0.0012 | ND     | ND     | 0.0180  |
| Tomatoes    | 0.0357 | 0.1250 | 0.0433 | 1.0833 | 0.0351 | 0.0530 | 0.2340 | 0.0021 | 1.6115  |
| Pepper      | 0.0678 | 0.4960 | 0.0150 | 0.0166 | 0.0660 | 0.0541 | 0.0123 | 0.0011 | 0.6629  |
| Cabbage     | 0.7892 | 0.0510 | 0.1980 | 1.0301 | 0.5230 | 0.5301 | 0.0620 | 0.0023 | 2.6629  |
| Onion       | 0.0500 | 0.0650 | ND     | 0.0280 | 0.0566 | 0.0612 | 0.0350 | 0.0031 | 0.2989  |
| Bitter leaf | ND     | ND     | 0.0371 | 0.0619 | 0.0320 | 0.0230 | 0.0230 | ND     | 0.17706 |
| Scent leaf  | ND     | 0.0250 | ND     | 0.0650 | 0.0212 | 0.7210 | 0.0641 | 0.0002 | 0.8965  |
| Water leaf  | 0.0570 | 0.1390 | 0.0090 | 0.0610 | 0.0123 | 0.0230 | 0.4521 | ND     | 0.1254  |
| Pumpkin     | 0.0750 | 0.1060 | 0.0402 | 0.0600 | 0.0130 | 0.0210 | 0.0120 | 0.0012 | 0.0126  |
| Spinach     | 0.0570 | 0.0742 | 0.0711 | 0.0119 | 0.0201 | 0.0231 | 0.0342 | 0.0021 | 0.1650  |

**Key:** ND is not detected, THQ = total hazard quotient, HRI = health index.

The estimated hazard quotient calculated for the vegetable and fruit samples is shown in Table 3 above. The present study reviewed all the hazard quotients that are within the maximum value, except for Pb in cabbage, that have a hazard quotient of equal than 1, and that of tomatoes. These show cabbage and tomatoes may pose a health risk to both adults and children.

The hazard index, which is the total value of the hazard quotient, shows that tomatoes and cabbage have a hazard index of 1.6115 and 2.662, respectively. According WHO, if the hazard index calculated is greater than 1, such vegetables and fruits may pose a health risk to consumers, and they need continuous monitoring to avoid the potential health cases associated the heavy metals.

#### 4. Conclusion

In this present study on the heavy metals contamination in viable and fruit samples from Kaura Namoda, eight selected heavy metals, namely Ni, Cd, Cr, Pb, Fe, Cu, and Co, were generally within the WHO recommended value,



except for Cabbage and tomatoes, where the Pb concentration in cabbage and tomatoes is higher than the WHO recommended limit. The estimated calculated health index shows that cabbage and tomatoes are 1.611 and 2.66, respectively. Therefore, it shows that they pose a health risk to the consumers since the value is greater than 1. Conclusively, the presence of these heavy metals in the vegetables and fruits shows the level of environmental pollution that these vegetables and fruits might be transported. Therefore, continuous monitoring may provide essential information and the contamination of heavy metals in the fruits and vegetables.

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### **Competing Interests Statement**

The authors declare that they have no conflict of interest.

### **Consent for publication**

The authors declare that they consented to the publication of this study.

### **Authors' contributions**

All the authors took part in literature review, analysis, and manuscript writing equally.

### **Availability of data and materials**

Supplementary information is available from the authors upon reasonable request.

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